Appendix E(4)

BADLANDS FIRE ECOLOGY

1. FIRE ECOLOGY OF SPECIFIC VEGETATION COMMUNITIES

VEGETATION

In 1999, vegetation communities of Badlands National Park were mapped as part of the servicewide Inventory and Monitoring Program's vegetation mapping project. The National Vegetation Classification System for the park included 28 natural and semi-natural associations and two complexes. The natural associations are comprised of four woodland, ten shrubland, six upland herbaceous/grassland, four wetland and four sparse vegetation types. The semi-natural associations are comprised of one woodland and three grassland types. Note in the descriptions below, the "BADL study area" includes 0.9 million acres including the park and surrounding lands.

Woodlands

Dry Coniferous Forests and Woodlands

- *Juniperus scopulorum* / *Oryzopsis micrantha* Woodland
  Rocky Mountain juniper / Little-seed ricegrass Woodland
- *Pinus ponderosa* / *Juniperus scopulorum* Woodland
  Ponderosa pine / Rocky Mountain juniper Woodland

Riparian Deciduous Forests and Woodlands

- *Fraxinus pennsylvanica* - (*Ulmus americana*) / *Prunus virginiana* Woodland
  Green ash - (American elm) / Chokecherry Woodland
- *Populus deltoides* - (*Salix amygdaloides)* / *Salix exigua* Woodland
  Eastern cottonwood - (Peachleaf willow) / Sandbar willow Woodland
- *Elaeagnus angustifolia* Semi-natural Woodland
  Russian-olive Semi-natural Woodland

Woodlands are minor components of the regional vegetation, covering approximately 1.8% of the BADL study area. These are generally restricted to floodplains, drainage bottoms, toeslopes of sandhills, draws associated with eroding buttes, and slumps on butte and cliff faces. Rocky Mountain juniper (*Juniperus scopulorum*) forms the most common woodland in the project area, occurring as its purest form on drier slopes, along butte edges, and in upper draws. A special habitat occupied by Rocky Mountain juniper is the side-slope slump, where additional moisture collects following the landslide.

Rocky Mountain juniper often intergrades with other woodlands, especially ponderosa pine (*Pinus ponderosa*) and green ash (*Fraxinus pennsylvanica*). Ponderosa pine woodlands occur in the upper elevations of the South Unit, where cover values for ponderosa pine and Rocky Mountain juniper are often nearly equal. Throughout the Park's lower elevations, Rocky Mountain juniper and hardwood trees also intermix along a broad gradient, with hardwoods occupying more mesic sites. Green ash and American elm (*Ulmus americana*) are the most common hardwood trees present, occupying bottoms of draws, river floodplains, and toeslopes of sand hills. The upper portion of hardwood draws is commonly dominated by various shrub species, particularly American plum (*Prunus americana*) and western snowberry (*Symphoricarpos occidentalis*).

Wetter mesic sites within the park support stands of Eastern or plains cottonwood (*Populus deltoides*) trees. Along with peachleaf willow (*Salix amygdaloides*), these typically occur within the Park as small clumps along minor streams, around seeps and springs, and around ponds.

<u>Shrublands</u>

Dry Plains Shrublands

- *Artemisia filifolia* / *Calamovilfa longifolia* Shrubland
  Sand sagebrush / Prairie sandreed Shrubland
- *Chrysothamnus nauseosus / Pseudoroegneria spicata* Shrubland
  Rubber rabbitbrush Shrubland
- *Rhus trilobata* / *Carex filifolia* Shrub Herbaceous Vegetation
  Three-leaved Sumac / Threadlead Sedge Shrub Herbaceous Vegetation
- *Yucca glauca / Calamovilfa longifolia* Shrub Herbaceous Vegetation
  Soapweed Yucca / Prairie sandreed Shrub Herbaceous Vegetation

Mesic Plains Shrublands

- *Artemisia cana / Pascopyrum smithii* Shrubland
  Silver sagebrush / Western wheatgrass Shrubland
- *Prunus virginiana - (Prunus americana)* Shrubland
  Chokecherry - (American plum) Shrubland
- *Sarcobatus vermiculatus* / *Pascopyrum smithii* Shrubland
  Greasewood / Western wheatgrass Shrubland
- *Shepherdia argentea* Shrubland
  Silver buffaloberry Shrubland
- *Symphoricarpos occidentalis* Shrubland
  Western snowberry Shrubland

Riparian Shrubland

- *Salix exigua* Temporarily Flooded Shrubland
  Sandbar willow Temporarily Flooded Shrubland

Shrublands make up approximately 6.6% of the BADL study area and occur mainly along river and creek floodplains, and on sand deposits, mesic slopes, and draws. The most widespread of all shrublands is silver sagebrush (*Artemisia cana*), which occurs regularly on floodplains and adjacent slopes. Silver sagebrush is usually found sparsely scattered throughout western wheatgrass (*Pascopyrum smithii*) grasslands, although in certain areas it may become quite dense or intermingle with other shrubs.

Sand hills support extensive stands of sand sagebrush shrubland (*Artemisia filifolia*), particularly in the southern half of the Park and project area. Where sand hills are reduced to sandy ridges or flats, stands of yucca (*Yucca glauca*) may replace or intermingle with sand sagebrush. Most yucca stands are located along the margins of buttes, on low sandy ridges, and on dry canyonsides.

Mesic draws, swales, slopes, and drainages all through the study area provide enough moisture to sustain patches of various broad-leaved shrubs, in addition to the silver sagebrush described above. Among the more common are western snowberry, American plum, and occasional three-leaved sumac (*Rhus trilobata*). Western snowberry is the most prevalent, occurring as relatively small stands or clones at the heads of draws or covering low swales. American plum often occurs adjacent to western snowberry or within openings of green ash. American plum typically grows in clumps that produce almost impenetrable thickets. Three-leaved sumac is present at the park as both very dense (moist conditions) and very sparse (dry conditions) shrubland types. Typically, this shrubland occurs as sparse stands along the rims of buttes.

The remaining shrublands represent relatively rare types found only in a few locations in and around the park. Sandbar willow shrublands grow in saturated ox-bows or cut-banks of Sage Creek in the North Unit and Fog Creek in the South Unit (Figure 15). One very large stand is located along the Conata Basin Road just outside of the Park boundary. Habitat similar to and slightly drier than that of sandbar willow may contain clumps of silver buffaloberry (*Shepherdia argentea*). Greasewood shrublands are known only from two small patches on Cuny Table in the South Unit and a small hilltop in the Sage Creek Wilderness of the North Unit. Finally, rabbitbrush (*Chyrsomthamnus nauseosus*) shrubs become dominant in disturbed sites throughout the project area, such as areas of road-construction.

<u>Grasslands</u>

- Prairie Dog Town Complex

Dry Mixedgrass Prairies

- *Bouteloua gracilis - Buchloe dactyloides* Xeric Soil Herbaceous Vegetation
  Blue grama - Buffalo grass Xeric Soil Herbaceous Vegetation
- *Calamovilfa longifolia - Carex inops ssp. heliophila* Herbaceous Vegetation
  Prairie sandreed - Long-stolon sedge Herbaceous Vegetation
- *Pascopyrum smithi - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation
  Western wheatgrass - Blue grama - Threadleaf sedge Herbaceous Vegetation
- *Schizachyrium scoparium - Bouteloua* (*curtipendula, gracilis*) - *Carex filifolia* Herbaceous Vegetation Little bluestem - (Sideoats grama, Blue grama) -Threadleaf sedge Herbaceous Vegetation
- *Stipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation
  Needle-and-thread - Blue grama - Threadleaf sedge Herbaceous Vegetation

Mesic Mixedgrass Prairies

- *Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation
  Western wheatgrass - Green needlegrass Herbaceous Vegetation

Introduced Grasslands

- *Agropyron cristatum - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation
  Crested wheatgrass - (Western wheatgrass) Semi-natural Herbaceous Vegetation
- *Bromus inermis - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation
  Smooth brome - (Western wheatgrass) Semi-natural Herbaceous Vegetation
- *Poa pratensis - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation
  Kentucky bluegrass - (Western wheatgrass) Semi-natural Herbaceous Vegetation

Riparian/Wet Meadows

- *Eleocharis palustris* Herbaceous Vegetation
  Pale spikerush Herbaceous Vegetation
- *Panicum virgatum* Herbaceous Vegetation

Switchgrass Herbaceous Vegetation
- *Spartina pectinata - Carex* spp. Herbaceous Vegetation
  Prairie cordgrass - Sedge species Herbaceous Vegetation
- *Typha* spp. - *Scirpus* spp. - Mixed Herbs Great Plains Herbaceous Vegetation
  Cattail species - Bulrush species - Mixed herbs Great Plains HerbaceousVegetation

Sparse vegetation can be found within areas of established prairie dog towns (approximately 2% of the project area). Prairie dog towns occupy deeper soils on large flats dissected by many drainages, such as in the Conata Basin. Prairie dogs may alter grassland vegetation types over time through their cycle of burrow establishment, grazing, and burrow abandonment. This constant use causes the native vegetation to revert back to an early successional state, *i.e.* a weedy, forb-dominated community.

There is a diverse grassland mixture that intermingles in small units across the landscape. Western wheatgrass is the predominant grass occurring in the project area. This sod-forming grass thrives on clayey soils were it ranges from almost pure, monotypic stands on clay to a true mixed grass prairie on silty/sandy clays or loamy clays. Common associated species include various forbs and grasses such as prairie coneflower (*Ratibida columnifera*), white milkwort (*Polygala alba*), needle-and-thread (*Stipa comata*), and prairie dropseed (*Sporobolus heterolepis*).

Two non-native annual grasses, Japanese brome (*Bromus japonicus*) and downy brome (*B. tectorum*) are also usually present to some degree in all grassland associations, especially western wheatgrass stands. Western wheatgrass also tends to be replaced in drier areas or places with increased grazing by blue grama. This shorter grass often grows in association with needle-and-thread and threadleaf sedge (*Carex filifolia*), especially around the extremely dry edges of buttes and small tables. On gravelly soils, side draws, and broad swales, little bluestem becomes dominant, often in association with side-oats grama (*Bouteloua curtipendula*).

Unique and predictable grassland associations for this project include switchgrass, which occurs in very wet, shallow basins, and western wheatgrass / green needlegrass, which is present on selected hills, slopes, and buttes. The Western Wheatgrass / Green Needlegrass Association is present on small rises and slopes of the North Unit and in somewhat flat mesic sites on buttes in the South Unit.

Regions throughout the project area that were disturbed historically by agricultural or transportation activity are primarily re-vegetated by non-native grass species. Representative locations include road corridors in the Park seeded with smooth brome (*Bromus inermis*), old fields in the North Unit seeded with crested wheatgrass (*Agropyron cristatum*), and old pastures on Sheep Mountain Table grazed by sheep and invaded by Kentucky bluegrass (*Poa pratensis*). Other relatively common non-native species found in various disturbed sites include alfalfa (*Medicago sativa*), Canada thistle (*Cirsium arvense*), and giant ragweed (*Ambrosia trifida*). A biennial, yellow sweetclover (*Melilotus officianalis*) is an exotic that is widespread within the North Unit of the Park.

Badlands Sparse Vegetation

- Badlands Sparse Vegetation Complex
  Badlands Sparse Vegetation Complex
- *Artemisia longifolia* Badlands Sparse Vegetation

Long-leaf sagebrush Badlands Sparse Vegetation

- *Eriogonum pauciflorum* - *Gutierrezia sarothrae* Sparse Vegetation
  Small-flowered wild buckwheat - Snakeweed Sparse Vegetation
- Eroding Great Plains Badlands Sparse Vegetation
  Eroding Great Plains Badlands Sparse Vegetation
- Shale Barren Slopes Sparse Vegetation
  Shale barren slopes Sparse Vegetation

Four associations were found in the sparsely vegetated badlands (approximately 19.2% of the project area) ranging from completely barren slopes to vegetated erosion fans. Badlands sparse vegetation develops on siltstone, volcanic ash, and claystone eroded to form pinnacle, cliff, mound, outwash fan, and intermittent drainage habitats. Also, a relatively unique badlands formation occurs on large expanses of low hills covered by chalcedony, a flat, crystalline rock with properties similar to quartz. Drought-tolerant shrubs such as silverscale saltbush (*Atriplex argentea*) and broom snakeweed (*Gutierrezia sarothrae*) and annual forbs can be found dispersed throughout variable badlands environments/habitats.

2. FIRE EFFECTS

Researchers are in agreement that fire provides an overall benefit to the continued growth, health, and maintenance of the mixed grass prairie ecosystem. (Vogl 1979, Wright and Bailey 1980). And although there appears to be some conflict in research findings relative to whether fire benefits or harms particular species (and the degree of benefit or harm resulting to affected species), there is essential agreement that for the mixed grass prairie fire plays an integral role in maintaining the ecosystem.

Given the rapid growth characteristics and the chemical composition of most mixed-grassland species, decomposition occurs slowly in the absence of fire in this ecosystem. Fires thus remove stagnant, dead plant accumulations while converting that mass to ash and charcoal. The blackened, burned areas protect underlying soils by joining remaining unburned vegetation and charcoal bits and help to raise the soil temperature by several degrees, particularly in the spring. The ash/charcoal material returns a number of minerals and salts to the soil, thus recycling them for new plant growth. More importantly, the higher temperatures increase fungal, bacterial, and algal activity which in turn increases available nitrogen. The increased microorganism activity also helps to increase soil temperatures while aiding in nutrient recycling. Fire generally improves mixed-grassland soils without leading to increased erosion. In addition to increasing nitrification of the soils and increasing minerals and salt amounts in the soil, the ash and charcoal residue resulting from incomplete combustion aids in soil buildup and soil enrichment by being added as organic matter to the soil profile. The added material works in combination with dead and dying root systems to make the soil more porous, better able to retain water, and less compact while increasing needed sites and surface areas for essential microorganisms, mycorrhiza, and roots. In general, fires tend to stimulate plant growth, resulting in larger, more vigorous plants, greater seed production, and increased protein and carbohydrate contents. Herbivores often prefer post-fire vegetation because it is more palatable and nutritious. When fires burn in mosaic patterns, potential animal cover remains while vegetation increases. Fires tend to increase species diversity, and reduce woody species relative to grass and forb species. (Vogl 1979, Wright and Bailey 1980).

Research data relative to fire's effects on a great number of mixed-grassland vegetation species are lacking. However, there are some data available for some species. It must be restated that some data seem to be in conflict. This may result from the type of fire (wildfire vs. prescribed fire; head fire vs. backing fire), season of fire (spring, summer, fall, winter); climatic conditions (lightning fires accompanied by rain vs. lightning starts during drought conditions); area of study (Park or Park-type lands vs. similar lands located further from the Park); and research methods used. Thus, data summarized here can serve as only general guides for expected effects of fire on a particular species. It is imperative that as part of the overall fire management program, site specific/species specific monitoring be conducted and observations permanently recorded in order that more accurate conclusions can be drawn as to the best method of returning the Park to a more natural fire regime and the result of using prescribed fires to aid the return to and continuation of that natural regime.

3. EXISTING FINDINGS PERTINENT TO FIRE MANAGEMENT OF SEVERAL PLANT AND ANIMAL SPECIES FOUND IN THE PARK INCLUDE:

Western wheatgrass *(Agropyron smithii)* - Herbage yield reduced for up to three years following wildfire and prescribed fire in semi-arid mixed prairie; remained the same or increased following May, September, and August wildfires, though herbage yield may be reduced in mesic mixed prairie; increases found following prescribed burns in April and March with some decrease following late May prescribed burn. There was also a decline noted in unburned areas (Wright and Bailey 1980). Near Miles City, Montana, another study of prescribed fire results showed the amount produced substantially lower following early spring burning versus fall burning (but both higher than on unburned control plots) although yields similar by the following spring. June yields were greater on burned plots versus unburned, control plots. Soil moisture found to have strong influence. Forage production may or may not be increased where this species is dominant. The time of year measurements are taken can vary findings substantially (White and Currie, 1983).

Little bluestem *(Andropogon scoparius)* -Data from prescribed fires in the forest-grass ecotone in the South Dakota Black Hills area indicate that burning in the spring to late spring promoted an increased production by this species. Conversely, a late winter/early spring burn (early March) resulted in severe harm to little bluestem. The conclusion drawn was that late spring burns under normal to above average moisture conditions are useful to increase yields of this species. Other spring prescribed fires in the eastern edge of the mesic mixed prairie had similar results (Wright and Bailey 1980). For comparison, data exist to show that fires in dry years in the southern Great Plains can greatly decrease yields while fires in wet years can greatly increase the yields. Similar results were found following wildfires in the central Great Plains in both the mixed grass and tall grass prairies. The key seems to be to conduct the burns in the late spring in years of at least average moisture conditions to get an increase of this species (Wright and Bailey 1980).

Blue grama *(Bouteloua gracilis)* - Some reduction of yield resulting from a spring prescribed burn, with full recovery by the third following year in a semi-arid mixed prairie locale; frequency reduced following late-May and fall wildfires in a mesic mixed prairie setting; although with early spring burns increases were found (Wright and Bailey 1980). Another study near Miles City, Montana revealed that using prescribed fire, blue grama yields were reduced early in the growing season and increased in late summer. However, results differed between this study and those following wildfires. Probably, by reduction of other competing species, blue grama had its highest herbage yield following spring burning (although better reduction of the other competing species may be greater using fall burns).

Upland sedges *(Carex spp.)* - Sedges generally tolerate fire very well. The season of a fire has the greatest effect on these plants (Wright 1978). For the Threadleaf Sedge, (Carex filifolia), a low postburn precipitation may delay full recovery until postfire year 2 or 3 or longer, depending on the severity of the burn. In South Dakota, productivity was increased by burning in April and October when precipitation was above average but was reduced when postburn precipitation was low (Whisenant and Uresk 1989). To maintain a good stand, plants should not be burned during period of drought, and burn severity should be light to moderate (Brand 1980). Therefore, if postfire precipitation is adequate, it appears that light-moderate severity fires (particularly spring fires) often cause only minimal damage to threadleaf sedge.

Needle and thread grass *(Stipa comata)* - Needle-and-thread is severely damaged by fire. This grass is generally killed when aboveground vegetation is consumed by fire. Fire effects depend on the season of burn and phenology, as well as on fire intensity and severity. Site conditions and climatic factors can also play a significant role. Needlegrasses are among the least fire resistant of the bunchgrasses (Young, Evans, and Major 1977). This species begins growth in the spring or early summer and lacks the pronounced dormant period in late summer that is typical of many other grasses. Consequently, fire is most injurious in midsummer and least detrimental in late spring or fall (Volland and Dell 1981).

Green needle grass *(Stipa viridula)* **-** Specific effects of fire depend on the season of burn, phenology, size of individual plants, and fire intensity and severity. During some high-severity fires, heat may be transferred below the soil surface by the foliage of green needlegrass, thereby increasing the amount of damage the plant receives. Needlegrasses often exhibit subsurface charring. In general, green needlegrass plants with a lower ratio of dead to living plant material and less fuel volume generally respond more favorably to fire than larger plants do (Wright and Klemmedson 1965).

Japanese brome *(Bromus japonicus)* **-**Except in wet years, fire tends to reduce Japanese brome (non-native) populations. The reduction usually lasts for only 1 or 2 years (Gartner and White 1986). Some seed is killed by fire, but seedbank reserves, reproductive capacity, and competitive ability of Japanese brome are usually sufficient to allow for re-population of an area within 2 years unless the site is reburned (Whisenant 1985). Since litter accumulations are more critical for germination and seedling establishment when precipitation is low, drastic population reductions can be expected when burning is followed by below-average precipitation (Whisenant 1990). Kirsch and Kruse (Kirsch and Kruse 1973) hypothesized that the successful establishment and spread of Japanese brome across the Northern Great Plains is a direct result of fire suppression: the resulting thicker surface mulch created a more mesic microenvironment for seeds and seedlings (Kirsch and Kruse 1973). Japanese brome populations will probably continue to increase in the absence of fire (Whisenant 1990). However, he cautions managers to balance the benefits of litter against the need to reduce Japanese brome when preparing fire management plans. Benefits of litter include soil stabilization and insulation, moisture retention, and promotion of perennials (Vogl 1974).

Smooth brome *(Bromus inermis)* **-** Smooth brome is a cool season exotic that is especially troublesome in disturbed portions of old pastures in the tallgrass and mixed prairie regions. Although less invasive than Kentucky bluegrass, with which it often occurs and is managed, it is also less responsive to management. The optimal timing for control of Smooth brome by burning appears to be in boot stage, which may be as early as mid-April in the central Great Plains or in the northern plains. Early spring (late March-April) or late-season (late summer-fall) fire can increase Smooth brome productivity (Higgins, Kruse, Piehl 1989 and Hughes 1985) especially when Smooth brome has become sod-bound. Late spring fire generally damages cool-season grasses such as Smooth brome (Bailey 1978 and Masters, Vogel 1989). Old, Kirsch and Kruse, and Blankespoor have reported reductions in Smooth brome with late spring burning. Blankespoor and Larson's 1994 prescribed fire-water treatment study suggests that prescribed late spring fire will most effectively control smooth brome in wet years. They recommend continuing a program of prescribed burning through drier years, however. Since they found that smooth brome increased in importance without burning, and that increases were greatest when initial smooth brome biomass was low, they concluded that failing to burn smooth brome in dry years is likely to accelerate its expansion.

Downy brome/Cheatgrass *(Bromus tectorum)* -This non-native grass is not appreciably affected by burning although production may be reduced the first year. The earlier the fire, the greater the degree of reduction (Stewart and Hull 1949). Fires in pure cheatgrass stands tend to be less common in the spring or early summer. Fires generally occur in the summer after seed is shed and is less vulnerable to burning. Reduction of cheatgrass under these conditions is not great (Tisdale and Hironaka 1981). Fire reduces cured plants to ash, but fire intensity may not be great enough to consume the litter layer, even if associated shrubs burn. Since cheatgrass produces prolific quantities of seed, even a large reduction in the seed pool will not prevent it from regaining dominance on a site (Young, Evans, and Weaver 1976). Must be cautious with this non-native grass because early summer fires can also kill perennial grasses and facilitate increases in cheatgrass.

Kentucky bluegrass *(Poa pratensis)* -There is some disagreement whether Poa pratensis is native in the northern tier of states and Canada (Fernald 1950, Great Plains Flora Assoc 1986, Gleason and Cronquist 1953) or native in Eurasia and introduced throughout its North American range (Hitchcock 1950, Mohlenbrock 1972, USDA 1948). This species is a major problem throughout the tallgrass and mixed grass prairies. In natural areas it competes with native species, reducing species diversity and altering the natural floristic composition. In northern mixed prairie (north of Nebraska sandhills) Poa is believed to compete directly with cool season native grasses (Steuter pers. comm.). North of the Nebraska sandhills in the Dakotas, there is a more even mix of native warm and cool season grasses (Steuter pers. comm.). There is only a short period of one or two weeks between the greening-up of Poa and of native co-dominant Stipa species. Unless fires are timed exactly within this spring period, the advantage of controlling Poa will be offset by damage to native cool season grasses. Results from a study by Schacht and Stubbendieck (1985) in Nebraska suggest that it is not only spring injury to Poa, but the shift of competitive advantage to warm season natives that makes fire an effective tool for range conversion in mixed prairie. Because natural area management goals involve the replacement of Poa by native species, it is important to monitor not only the decrease in Poa, but the increase or retention of desired native species. This is important because under sod-bound conditions Poa could decrease without any benefit to native species (Kruse pers. comm, Volland pers. comm.).

Canada thistle *(Cirsium arvense)* -Canada thistle is a herbaceous perennial in the aster family. It is an exotic weed that was introduced to the U.S., probably by accident, in the early 1600's and by 1954, had been declared a noxious weed in forty three states. In Canada and the U.S., it is considered one of the most tenacious and economically important agricultural weeds, but only in recent years has it been recognized as a problem in natural areas. At Badlands National Park it has invaded ~10,000 acres depending on the year and the mapping techniques used at the time. To keep this weed from expanding its range you must eliminate or control, to the greatest extent possible, seed production. Complete control is difficult because of the perennial root system, abundant seed production, and widespread and diverse habitat of the plant. Prescribed spring burning may be a useful means of slowing the spread of Canada thistle. Spring fires would reduce the number of mature plants. They would also reduce the number of functional flower heads, resulting in lower seed production and a slow-down in the spread of new plants. Dormant-season fire is also beneficial to many native grass species, would interfere with Canada thistle growth and reproduction, and possibly its spread (Young 1986). Patches of Canada thistle were reduced in Minnesota after 4 years of consecutive spring burning of low to moderate intensity (Becker 1989). Density and aboveground biomass were unchanged after a spring fire (May, before growth began) and increased after both summer (August, peak of growth) and fall (October, winter dormancy) fires in Manitoba. The increase on the fall fire was lower than on the summer fire (Thompson and Shay 1989).

Silver sagebrush *(Artemisia cana ssp. cana)* - Unlike the majority of woody Artemisias, the silver sagebrush complex is moderately resistant to fire-caused mortality. Following fire, plains silver sagebrush resprouts vigorously via root sprouts and rhizomes, and preburn coverages are rapidly regained. Research results from Montana indicate that as burn intensity and severity increase, plant mortality increases and regrowth decreases. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Western snowberry *(Symphoricarpos occidentalis) -* Western snowberry sprouts vigorously from the root crown and rhizomesfollowing fire; stands are usually denser in burnedthan in adjacent unburned areas. Spring and fall fires inducewestern snowberry sprouting, but frequent fires may reduce cover. Western snowberry probably establishes from off-site seed dispersed bybirds and mammals. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Chokecherry *(Prunus virginiana)* - Generalized fire effects information indicates that chokecherry is well-adapted to disturbance by fire. This species is moderately resistant to fire mortality, and, although easily top-killed,sprouts vigorously from surviving root crowns and rhizomes following most fires. To a lesser degree, postfire regeneration also involves the germination of off-site seed dispersed by mammals and birds. Recovery is relatively rapid following fire. Although initially damaged, plant numbers and coverages are typically enhanced for several years. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Silver buffaloberry *(Shepherdia argentea) -* Silver buffaloberry has fair tolerance to fire in the dormant state andsprouts from rootstocks following fire. In North Dakota the green ash/chokecherry and boxelder/chokecherry habitat types, in which silver buffaloberry is common, are adapted to fire. When main trunks of most shrubs and trees in these habitat types are damaged by fire, the plants sprout from the root crown. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Soapweed yucca *(Yucca glauca) -* Soapweed yucca is described as "extremely difficult to kill with fire". This species produces underground rhizomes which are presumably well-protected from the effects of heat by overlying soil and a thick, protective bark-like covering. Seed germinates well and seedlings establish readily on newly disturbed areas with little vegetation, such as recently burned sites. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Ponderosa pine *(Pinus ponderosa)*—Interior ponderosa pine depends on frequent surface fires to maintain stand health and stability (Biswell, Kallander and Komarek 1973). Fire exclusion has profoundly influenced the stability of interior ponderosa pine stands (Cooper 1960). The following management problems are associated with reduced fire frequencies: (1) overstocked sapling patches, (2) reduced growth, (3) stagnated nutrient cycles, (4) increased disease, insect infestations, and parasites, (5) decreased seedling establishment, (6) increased fuel loadings,

(7) increased vertical fuel continuity due to dense sapling patches, and (8) increased severity and destructive potential of wildfires (Covington and Sackett 1984). The effect of fire on interior ponderosa pine is generally related to tree size, fire intensity, and tree density (Alexander 1987). Low intensity fires readily kill seedlings less than 12 inches in height (Biswell, Kallander and Komarek 1973). Larger interior ponderosa pine seedlings can sometimes survive heat generated by low intensity surface fires, especially dormant season fires (Fischer and Clayton 1983). Larger seedlings, saplings, and pole-sized trees are damaged but not killed by low intensity fires. Beyond the pole stage, interior ponderosa pine is quite resistant to the majority of ground fires (Schuber, Heidmann and Larson 1970). For the season of burn: Interior ponderosa pine usually survives fires during the dormant season, largely because insulating scales form once leader growth stops (Ryan 1982) and because dormant season fires are usually relatively cool (Dieterich 1979). Trees are least resistant to thermal damage during early spring and most resistant in the fall when dormant (Hare 1961). Trees can withstand up to 50 percent crown scorch from fall burning but only 30 percent crown scorch from spring burning (Mohr 1984).

Green ash *(Fraxinus pennsylvanica)* - Generalized fire effects information indicates that green ash is adapted to disturbance by fire. If the fire is hot enough to girdle even mature trees, which have little protection from burning because of their relatively thin bark, this species will sprout prolifically from the root crown when the main stem is damaged. To a lesser degree, postfire regeneration most likely involves the germination of on-site canopy stored seed and/or off-site wind or water dispersed seed as well. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Rocky Mountain Juniper *(Juniperus scopulorum)* - Young Rocky Mountain juniper which has a compact crown and thin bark, is easily killed by fire. It can be killed when the stem or crown is scorched. Older Rocky Mountain junipers have thicker bark and an open crown, and can survive cool fires. Older trees are generally killed by hot fires or when low-hanging branches allow the fire to enter the crown. Rocky Mountain juniper does not re-sprout after fire. Reestablishment is primarily through water or animal-dispersed seed. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Eastern Cottonwood *(Populus deltoides)* - The bark of older cottonwoods can be up to 4 inches (10 cm) thick at thebase, affording fire protection. Trees less than 20 years old are susceptible to fire but may re-sprout. Plains cottonwood (var.occidentalis) is able to produce sprouts from the root crown and the stump after fire. The literature is unclear whether eastern cottonwood (var. deltoides) is adapted to fire in this way. Cottonwood seedling regeneration is favored following disturbances suchas fire and flood. Fire thins the overstory, allowing more light penetration, and exposes the mineral soil so that seeds are able to establish if soil moisture is adequate. [excerpted from Fire Ecology Information System, for references see www. fire.org/feis]

Pronghorn/Antelope *(Antilocapra americana)* - As a primarily forb-eating species with strong requirements for open cover, pronghorn are favorably influenced by the increase in herbaceous species and reduction of shrubs after fire (Higgins, Kruse and Piehl 1989). Nutritional benefits of fire on forage may last up to 4 postfire years with an increase in primary productivity for a longer period depending upon plant species (Badlands National Park Conservation Plan 1966).

Bison *(Bison bison)* - Fire is important in creating and maintaining bison habitat. Fire regenerates grasslands and enhances production, availability, and palatability of many bison forage species (Campbell and Hinkes 1983). Prescribed fire is effective in mitigating bison impacts on black-tailed prairie dog colonies. Bison use of a black-tailed prairie dog colony was compared before and after a prescribed fire on adjacent, uncolonized grassland at Badlands National Park, in 1979 and 1980. Cow-calf herds increased their use (measured as hours of feeding time) of the burned grasslands by a factor of 12 and decreased their use of the colony by 30 to 63 percent following the burn. To decrease bison impacts on black-tailed prairie dog colonies, burns should be located a "considerable" distance from colonies (Coppock and Detling 1986).

Black-tailed Prairie dog *(Cynomys ludovicianus)* -Fire can be used to stimulate the growth of dogtowns as well as to temporarily halt their rate of growth or to even reduce their size. Prescribed burns immediately adjacent to dogtowns can enhance dogtown expansion by reducing the height and density of bordering ground cover. Fires on areas removed from dogtowns will significantly reduce ungulate use of colony sites. Under such conditions prairie dogs must on their own accomplish the reduction of ground cover required for expansion into uncolonized areas (Klukas 1988).

Bighorn Sheep (*Ovis canadensis*) - Prescribed burning and its associated human activity in bighorn sheep range may increase stress levels in a population. Herd condition should be considered when planning time of fire. No information is available regarding the direct effects of fire on bighorn sheep.

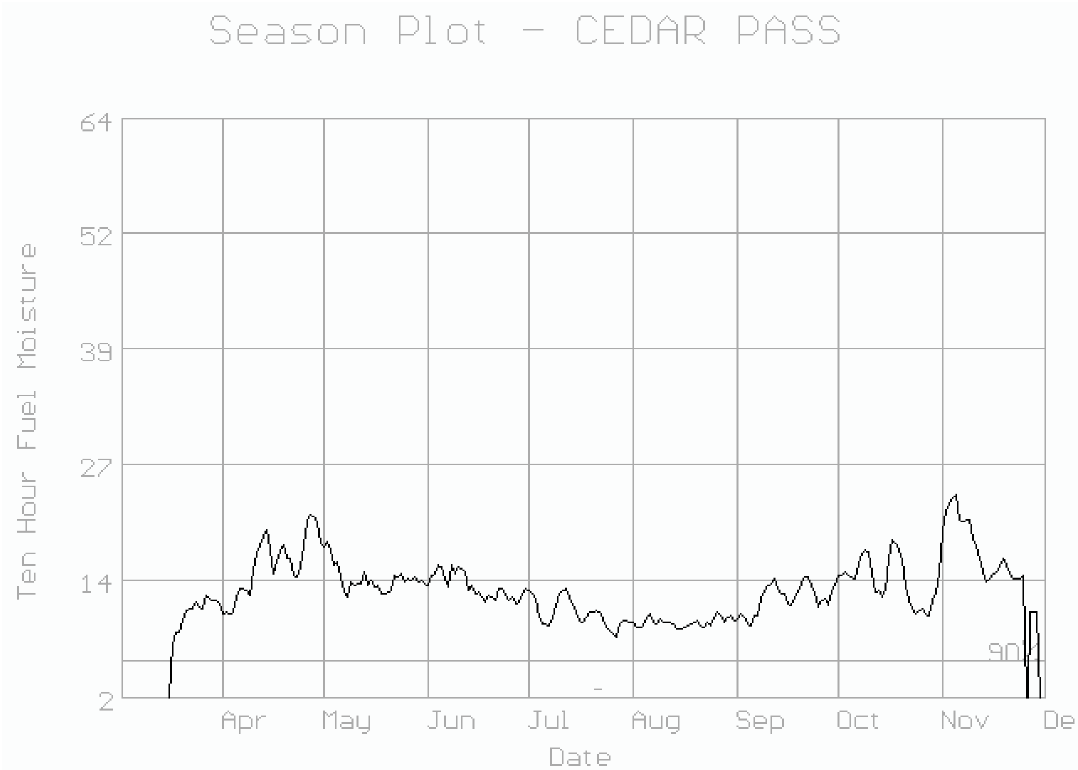
Many bighorn sheep populations originally occurred in areas with frequent fire intervals. Fire exclusion, which has allowed conifers to establish on grasslands, has decreased both the forage and security values on many bighorn sheep ranges. Burning may regenerate range lands and enhance the production, availability, and palatability of important bighorn sheep forage species. Burning can increase visibility for bighorn sheep. Research has shown that on burned sites bighorn sheep use areas more distant to escape terrain than on adjacent unburned sites. Fire can negatively affect bighorn sheep habitat when range condition is poor and forage species cannot recover, when non-sprouting species that provide important forage for bighorn sheep are eliminated, or when too much area is burned and forage is inadequate until the next growing season. Another potentially negative effect is when other species, especially elk, are attracted to prescribed burns intended to benefit bighorn sheep.

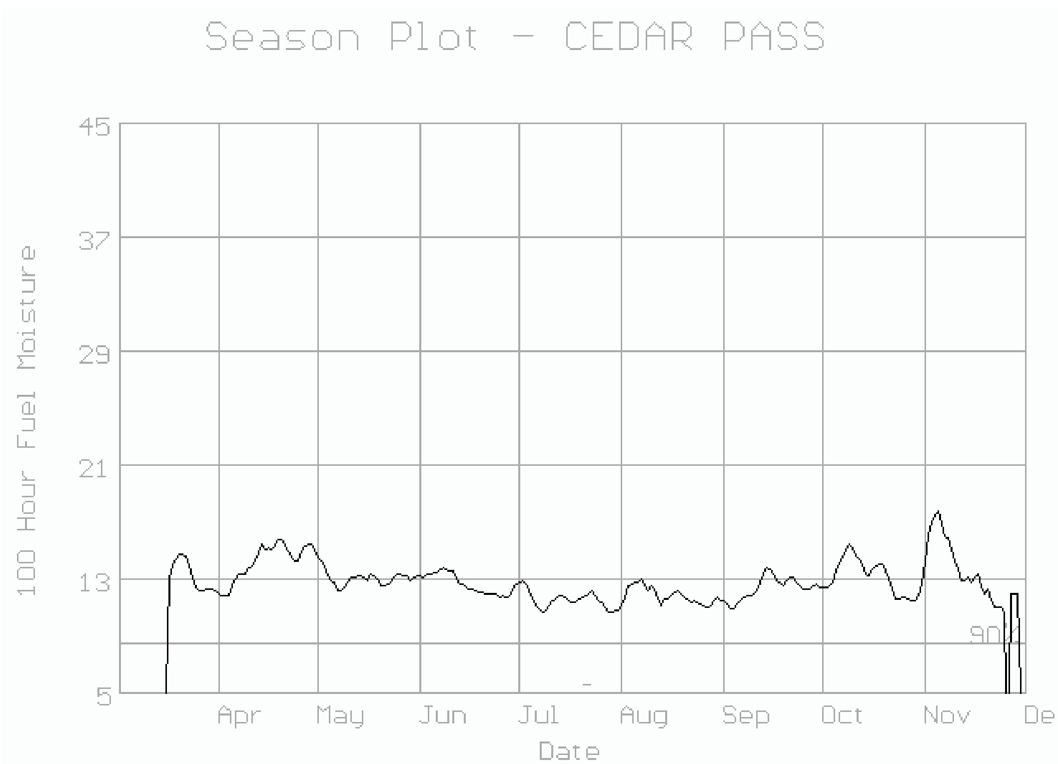
Prescribed burning has been widely used to increase the quantity and nutritional quality of bighorn sheep forage throughout North America. In areas where the available bighorn sheep range is large and provides alternative and distant wintering sites, fires should be prescribed or located in areas that would minimize the stress on sheep. Early spring fires, particularly on south and southwest aspects, may provide more spring forage than would otherwise be available for bighorn sheep.

Coyote (*Canis latrans*) - Coyotes are very mobile and can probably escape most fires. There are no reports of direct coyote mortality due to fire.

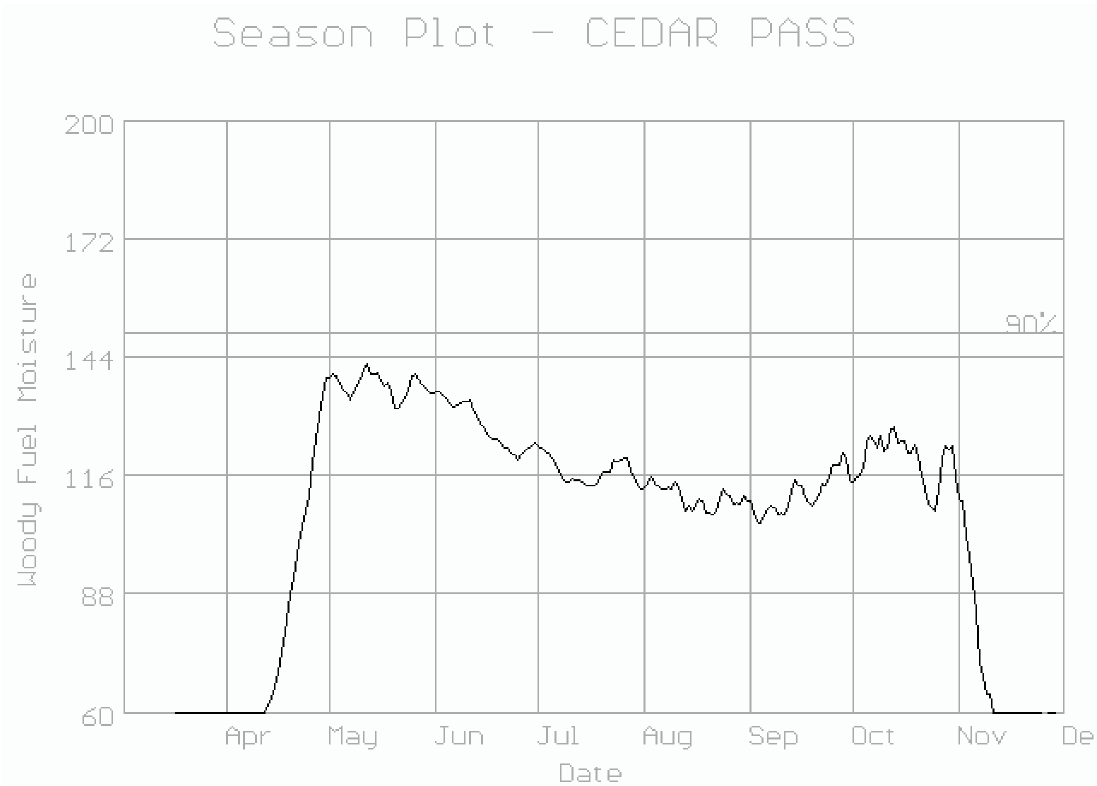
Fire may improve the foraging habitat and prey base of coyotes. Fires that reduce vegetation height and create open areas probably increase hunting efficiency by coyotes. Periodic fire helps to maintain habitat for many prey species of coyote. Fires that create a mosaic of burned and unburned areas are probably the most beneficial to many coyote prey species. Several studies indicate that many small mammal populations increase rapidly subsequent to burning in response to increased food availability. Fire often improves hare and rabbit forage quality and quantity for two or more growing seasons. Additionally, fire stimulates grass production, which should lead to an increase in small mammal populations. Prescribed burning that favors small mammals by creating ecotones and different age classes of vegetation would increase the prey base for coyotes and make hunting easier by opening up the habitat.

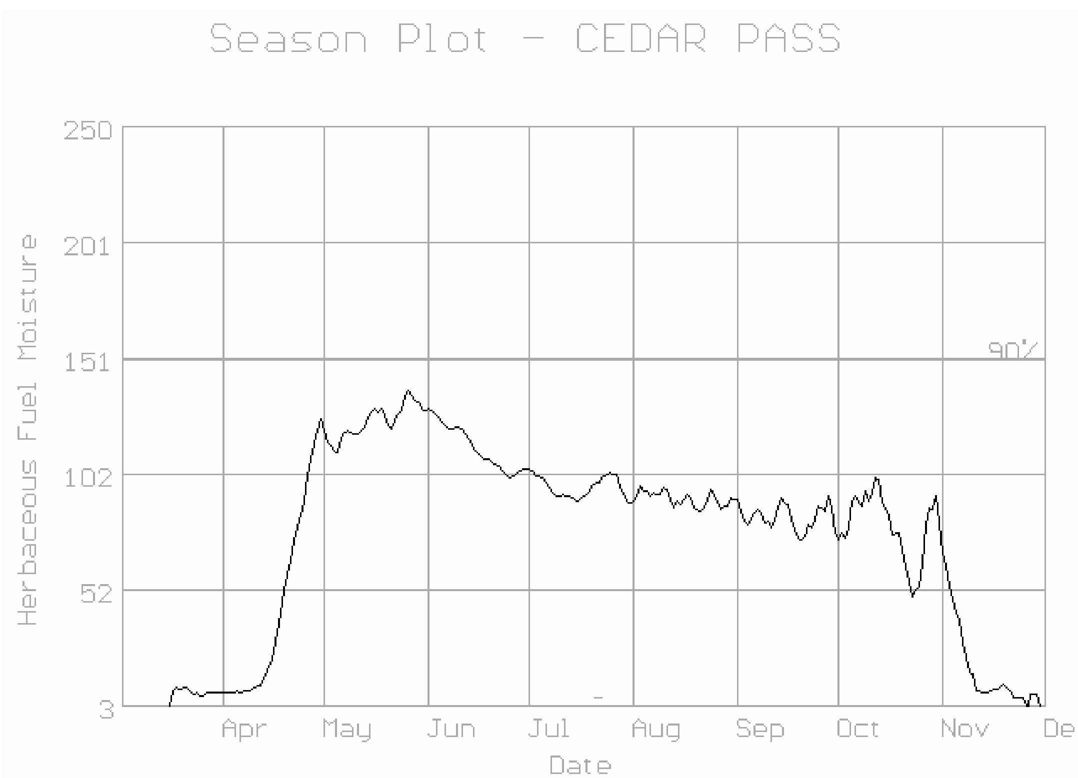
Seasonal Graphs of Average 10 and 100-hour Dead Fuel Moisture





Seasonal Graphs of Average Live Woody and Herbaceous Fuel Moisture





Seasonal Graphs of Average Burning Index and Energy Release Component